A LATE QUATERNARY *ANADARA*-BEARING DEPOSIT DISTURBED BY RANGITOTO LAVA

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With an Appendix *XRD analysis of the lapilli in R11/f148* by T. Sameshima, Geology Department, University of Auckland.

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ABSTRACT

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Flowing lava has rucked up à tuffaceous shelly sandy mudstone of shallow marine origin at high tide level on the west coast of Rangitoto Island, Hauraki Gulf. Radiocarbon ages of 25 430 ± 1000 BP and 37 600 ± 1800 BP on two shells of the locally extinct bivalve *Anadara trapezia* (Deshayes), which in other New Zealand sites is found in Quaternary deposits of warm water origin, indicate accumulation during the Last Glaciation. They suggest that the deposit remained essentially unlithified until disturbed by Rangitoto lava some 1100 years ago, that the tuffaceous content originated not from Rangitoto but from an adjacent North Shore centre (Onepoto, by mineral concentrations), and that either sea-level stood very near the present level 25 000-37 000 years ago or else significant fault movement may have occured associated probably with Holocene volcanism.

KEYWORDS: *Anadara trapezia* - Rangitoto lava - radiocarbon dating - Quaternary sea-levels - Last Glaciation.

INTRODUCTION

In 1985 one of us (SC) noted shelly sediment associated with lava on the western side of Rangitoto Island (Fig. 1). Some shells were collected and shown to the first author who recognised amongst them the Sydney mud cockle, *Anadara trapezia* (Deshayes), now extinct in the New Zealand region. We visited the site in July 1985 for more detailed observations and collecting

GEOLOGICAL SETTING

The site is at, and slightly above, high water mark among irregular lava masses forming a small island or off-shore reef c. 250 m at 143° from Red Beacon (grid ref. 732892 on NZMS 260 1:50 000 map sheet R11 - Fig. 1). The deposit lies 10 m west of a body of lava c. 6 m high and 2 m diameter known locally as "Queen Victoria", and consists of a short low ridge of sediment approximately 8 m long, 0.4 m high and up to 0.5 m wide striking 173°, with two low mounds of similar sediment 1 m apart and 1 m to the east in a line parallel to the ridge (Fig. 2A,B).

The sediment is of two types: dominantly grey-brown sandy mud with abundant marine shells and yellowish-brown sandy mud with few or no shells. In the former, colour results from the presence of many black grains of scoria or ash. The shells are well preserved, although some larger bivalves (e.g., *Perna*, *Pecten*, *Cyclomactra*) have been fragmented *in situ* (Fig. 2C), and may be slightly leached, but neither shells nor sediment show obvious indications of baking,

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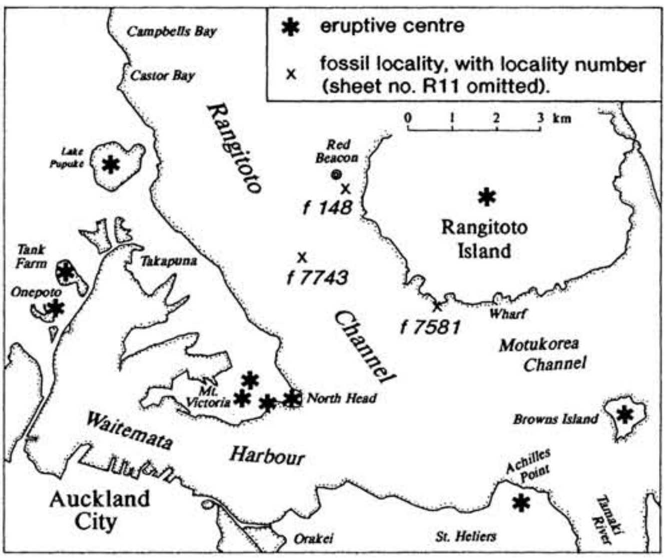

Figure 1. Locality map.

as occurs elsewhere beneath Rangitoto lava (Fleming 1944).

Many of the shells and shell lenses are oriented subparallel to each other, dipping steeply to the west, in concert with the contact between the two sediment types. This suggests the sediment ridge is a strike-ridge, with shells and bedding dipping c. 65° west, strengthened by a 50-100 mm thick unfossiliferous brecciated mudstone.

Relationship with the surrounding lava is difficult to ascertain. Contacts are with detached fragments or with modern beach debris (Fig. 1,2A). No contacts were seen with undoubtedly *in situ* lava. However, the general setting and mode of occurrence strongly suggest the ridge of marine sediment owes its disposition to effects of lava emplacement. The westwards advancing lava tongue plowed into soft sediment rucking it up into a west-dipping ridge. The shelly portion was sufficiently plastic for this disturbance to fragment larger shells but the thin mud layer was more coherent and shattered rather than flowed.

FAUNA

Apart from *Anadara*, all the species listed in Table 1 occur in the region today. Among the 28 molluscan species present the following are common: *Anadara* (juveniles), *Austrovenus*, *Chlamys*, *Caryocorbula*, *Lasaea*, *Ostrea*, *Paphies*, *Perna*, *Tawera*, *Trochus*, *Purpurocardia*.

In the field two species associations are apparent: (a) *Cyclomactra*, *Perna* and *Lasaea*, in which a fragment of *Alcithoe* was noted, and (b) *Anadara*, *Caryocorbula*, *Chlamys*, *Tawera* and *Purpurocardia*, with *Pecten* and barnacles. The former lies to the east of the latter and thus underlies it and is slightly older.

This sequence suggests deepening conditions, from intertidal rocks and mud (a) to a low tide or shallow subtidal site (b), a transgression perhaps little more than a few tens of millimetres, and 1-2 m at most (based on ranges of these taxa reported in Powell 1979).

If these two associations included *in situ* segments of original biocoenoses, some members of each, especially *Cyclomactra ovata*, *Anadara trapezia* and *Purpurocardia purpurata*, should occur as articulated specimens - this is not generally so. Therefore the above paleoecologic conclusion must be treated with caution.

The fact that *Anadara* is represented only by juvenile specimens is open to a number of interpretations: conditions were not optimal for its growth and it thus failed to reach maturity (an unlikely alternative given its numbers here); or individuals were displaced during development and died, and thus are not *in situ*. This latter argument is feasible because *Anadara*, in life, lies only half buried in estuarine mudflats (Hedley 1915 cited by Fleming 1944, Beu *et al.* 1990), and dead juveniles could be excavated and trans-

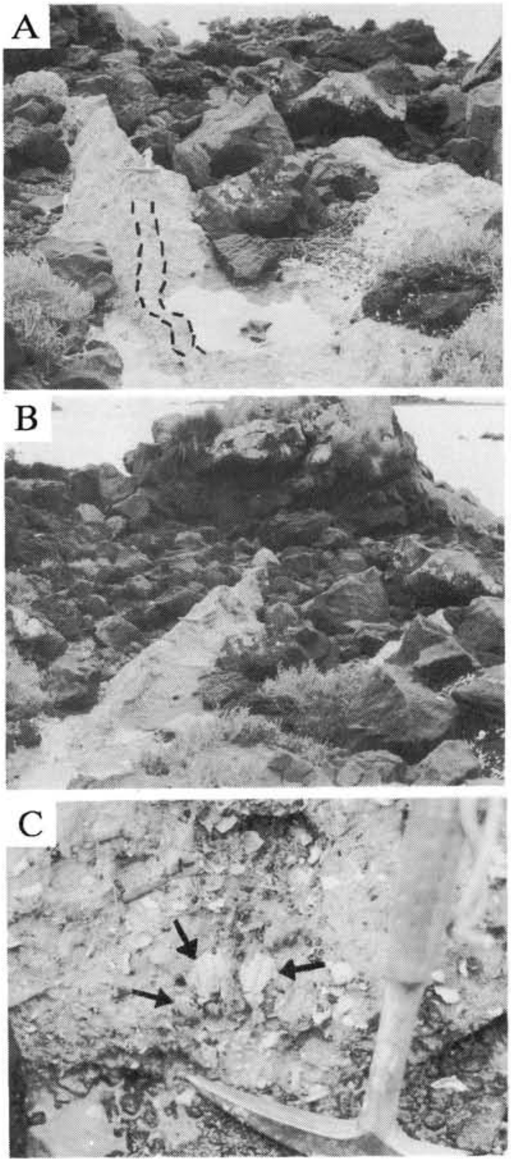

Figure 2A-C. (A) View approximately northwards of the two sediment ridges constituting fossil locality no. R11/f148 (in the archival NZ Fossil Record File) (hammer-head = 18 cm). Westerly ridge (LHS) is cored by more coherent mud bed (partly outlined) showing a steep westerly dip. (B) View north-northwestwards of the western sediment ridge projecting from among flow basalt fragments. (C) Close-up view of part valve of *Pecten novaezelandiae* (arrowed) fragmented *in situ*, presumably by movement within the sediment during flowage of lava.

Table 1. List of macrofauna in collection AU11910 from fossil locality no. R11/f148, western Rangitoto.

MOLLUSCA

Polyplacophora

Acanthochitona (Notoplax) mariae (Webster, 1908)

Gastropoda

Alcithoe arabica (Gmelin, 1791)
Amalda (Baryspira) mucronata (Sowerby, 1830)
Amalda (Gracilispira) novaezelandiae (Sowerby, 1859)
Calliostoma punctulatum (Martyn, 1784)
Eulimella levilirata Murdock and Suter, 1906
Leuconopsis obsoleta (Hutton, 1878)
Nozeba emarginata (Hutton, 1885)
Odostomia sp. cf. *haurakiensis* Laws, 1939
Odostomia takapunaensis Suter, 1908
Sigapatella novaezelandiae (Lesson, 1831)
Trochus (Coelotrochus) tiaratus Quoy & Gaimaird, 1834
Xymene pusilla (Suter, 1907)
Zeacumantus lutulentus (Kiener, 1841)
Zegalerus tenuis (Gray, 1867)

Bivalvia

Anadara trapezia (Deshayes, 1839)
Austrovenus stutchburyi (Gray, 1828)
Barnea (Anchomasa) similis (Gray, 1835)
Caryocorbula zelandica (Quoy & Gaimard, 1835)
Chlamys zelandiae (Gray, 1843)
Cyclomactra ovata ovata (Gray, 1843)
Irus (Notirus) reflexus (Gray, 1843)
Lasaea rubra hinemoa Finlay, 1928
Leptomya retiaria retiaria (Hutton, 1885)
Maorimactra ordinaria (E.A. Smith, 1898)
Nucula hartvigiana Pfeiffer, 1864
Paphies (Paphies) australis (Gmelin, 1790)
Pecten novaezelandiae Reeve, 1853
Perna canaliculus (Gmelin, 1791)
Purpurocardia purpurata (Deshayes, 1854)
Ruditapes largillierti (Philippi, 1849)
Saccostrea cucullata (Born, 1778)
Tawera spissa (Deshayes, 1835)
Tiostrea chilensis (Philippi, 1845)

ARTHROPODA: CIRRIPEDIA

Austromegabalanus (Notomegabalanus) decorus (Darwin, 1854)
Eliminius modestus Darwin, 1854.

ported even by the gentle wave and current action of an estuarine intertidal zone. *Leuconopsis* has been similarly transported from its high tide life position into slightly deeper conditions. *Barnea*, on the other hand, has been transported into these sediments from some adjacent intertidal soft rock exposure.

PREVIOUS RECORDS OF *ANADARA*

Anadara trapezia is a biostratigraphically useful mid to Late Pleistocene index fossil in New Zealand. It has been reported from various sites in the North Island, from Wanganui and Mahia Peninsula northwards (Crozier 1962, Fleming & Powell 1974, Beu *et al.* 1990), in strata ranging in age from mid Pleistocene (Putikian Substage of Castlecliffian Stage, c. 500 000-350 000 BP) to Last Interglacial (i.e., oxygen isotope stage 5, c. 80 000 BP), all beyond the range of radiocarbon dating.

A. trapezia has previously been reported from Rangitoto by Fleming (1944) and referred to by Crozier (1962). Occurrence was mentioned only as being in baked mud beneath a basalt flow and the locality was not more precisely documented. Neither specimens nor further information could be located in either New Zealand Geological Survey or Auckland Museum collections and records. Marine shells in baked sediments are known from Flax Pt, south-southwest Rangitoto, but are not known to include *Anadara*. Fleming's record must either refer to our present site, which is not baked, or be an unconcious error for another bivalve such as *Perna canaliculus*, the green-lipped mussel, which does occur in the Flax Pt sediment (collection R11/f7581, held in the University of Auckland Geology Department, which provided the sample for a radiocarbon date of 1100 ± 50 yrs BP - NZ440; Law 1986) (Fig. 1). The record is thus highly questionable, and should be ignored.

Many adult and subadult *Anadara trapezia* are held in private collections, in the Auckland Museum (uncatalogued) and in the NZ Geological Survey (collection GS11475, fossil record file no. R11/f7743). They came from dredgings made by the Auckland Harbour Board in 1974 in Rangitoto Channel at mid-channel between the Rangitoto beacon and Narrow Neck, 1.5-3.6 m below the seabed and 13-14 m below sea-level (Fig. 1). One other water-worn juvenile left valve is in Auckland Museum collections, also uncatalogued. It was found at Campbell's Bay on Auckland's North Shore. Without dating there is no way of comparing the Rangitoto Channel specimens with those reported here; they could be contemporary or of a different age. Beu *et al.* (1990) have assumed an age comparable with that of the present deposit, but this is not supported by the fact that *Anadara* shells from the Rangitoto Channel are mostly adult specimens, whilst none occurs amongst the juveniles in the collection recorded here.

PROBLEMS POSED BY THE SITE

This occurrence of *Anadara* can readily be interpreted as being in sediments more or less contemporaneous with the lava flow which has disturbed them. The rucked-up deposit, shells broken by internal movement in the soft sediment, and the included basaltic ash all suggest contemporaneity. With Rangitoto eruptions covering the period from c. 1100 BP to c. 190 BP (e.g., Robertson 1986), this deposit, if contemporaneous with the surrounding lava, would be significantly younger than any previously recorded occurrence of *Anadara* in New Zealand.

Alternatively, if the lava has flowed onto an older, fossil, seafloor, would the deposit still retain the plasticity to enable it to react as above to the arrival of a lava flow? Absolute dating thus becomes crucial.

RESULTS

RADIOCARBON DATING

Although diverse, the fauna consists mainly of small or thin-shelled taxa and no specimen is large enough for dating by the traditional ^{14}C method. Specimens of *Anadara* were submitted to the Institute of Nuclear Sciences (INS), Lower Hutt, for dating using the tandem accelerator.

Results from one shell (INS R11152) show $D^{14}C$ is -957.8 ± 5 per mille, with 4.2 ± 0.5% modern carbon (both as defined by Stuiver & Polack 1977), giving an age (based on the "Libby half-life" of 5568 years) of 25 430 ± 1000 years BP, at the end of oxygen isotope stage 3 (Martinson *et al.* 1987), an interstadial of the last Glaciation, at a time when sea-level was some

100 m lower than the present (e.g., Chappell & Shackleton 1986).

As this age was much older than expected, INS dated a second *Anadara* valve, with the following results: $D^{14}C$ is -991 ± 2 per mille, with 0.9 ± 0.2% modern carbon, giving an age of 37 600 ± 1800 radiocarbon years BP, a date which takes the deposit further back into the same interstadial, suggesting a sea-level c. 60 m lower than present. The possibility of both dates being significantly in error as a result of contamination by younger carbon is a problem recently pin-pointed, *inter alia* by Brown & Wilson (1988), and cannot be discounted

PRESENCE OF TUFF

Given these ages, the ash and tuffaceous material present cannot have come from Rangitoto, but alternative sources exist. To the southwest lie the North Shore centres of North Head, Mt Victoria, Lake Pupuke, Onepoto, and Tank Farm; and to the southeast there is Motukorea (Brown's Island) (Fig. 1). To address this problem a sample of the tuffaceous sediment was submitted to Dr T. Sameshima who reports (Appendix I) a close correspondence in mineral concentrations with tuff from the Onepoto centre, 7 km to the west-southwest (down-wind) of the Rangitoto site, and significant differences from those of most other nearby centres. The Rangitoto radiocarbon dates thus probably provide evidence for the time of eruption of Onepoto which has previously been estimated (Searle 1964) to be 40 000 years BP or older. Identification of a possible local source within the Auckland volcanic field also tends to negate the argument for the ages being too young due to carbon contamination for this field is not known to have been active before c. 60 000 B.P. (Searle 1964), although the possiblitiy of small age shifts caused by contamination remains.

DISCUSSION

PRESENCE OF *ANADARA*

From the above ages, not only is this the youngest record of *Anadara* in New Zealand, but it is also the only one of *Anadara* populating the New Zealand region during a glacial period. This record suggests that *Anadara* returned to New Zealand during the last interstadial of the Last Glaciation, establishing itself in the Auckland area, and was locally extinguished as temperatures dropped into the Last Glacial maximum of c. 18 000 yrs BP.

Temperatures during the Last Glaciation have been estimated for a few parts of New Zealand and there is some agreement that Last Glacial maximum temperatures were c. 5°C lower than present (e.g., McGlone *et al.* 1978, Soons 1979). Temperatures for the preceding interstadial are not clear but curves published for South Island glacial sequences and North Island speleothems (Burrows 1978) show estimates for the 38-25 000 BP period ranging from 0-5° lower than the present. Whatever the temperature at that time, it must have been high enough to accommodate *Anadara*.

Despite the claim by Kendrick & Wilson (1959) that temperature is not a limiting factor, Crozier (1962) concluded that the modern distribution of *A. trapezia* indicates it is likely to be sensitive to a particular temperature range. She recorded its modern range as from southern Queensland (annual temperature range 20.5-25°C) to Port Philip Bay, Victoria (11.7-19.61°C) and at Emu Point, Western Australia (15.5-19.5°C). No more recent study of its temperature tolerances has been published. Waters at the mouth of the Waitemata Harbour show a modern annual range of 18-23°C (Crozier 1962) and indicate, as Crozier has already pointed out, that *Anadara* could probably live in the region today, as it did during the interstadial 38-25 000 yrs ago when temperatures may have been comparable.

PRESENT ALTITUDE OF THE DEPOSIT

Sea-level did not stand at its present altitude at any time from 100 000 to 10 000 years BP (Chappell & Shackleton 1986). Thus a marine deposit from within that span could occur at present high water only as a result of either tectonic or volcanic uplift.

There is no geomorphic evidence of active faulting in the region. A major fault of post-Lower Miocene age runs about meridionally at the eastern edge of Rangitoto with a throw of c. 120 m to the west (Milligan 1977). Its precise age is unknown, but the throw is opposite to that required to raise the *Anadara* beds to their present level. Terrace levels in the Auckland area are consistent enough (Ballance 1968) to indicate general tectonic stability over the Quaternary, yet Pocknall *et al.* (1989) show that local tectonic uplift probably has occured in the Hauraki Gulf in postglacial times.

Local uplift associated with volcanism is a second, more feasible explanation. Geophysical modelling of the Rangitoto volcano (Milligan 1977) suggests initiation of activity in shallow waters with phreatomagmatic eruption due to contact of the rising magma with seawater or waterlogged sediment. Such explosive eruption could brecciate the country rock and displace it upwards.

A third possible explanation is that sea-level during the last interstadial did reach virtually the present level, as already claimed for the Auckland area by Searle (1964). McDougall & Brodie (1967) recognised the possibility for the western shelf off the North Island but concluded (p.43) that "the data do not lend themselves to recognition of relatively high (interstadial) levels that might have been located at or near present sea level". Positive evidence would be preserved only rarely in stable areas, and Late Quaternary uplift rates for the east Auckland region have been calculated at 0.0-0.15 mm/yr (Pillans 1986). On a global scale Carew *et al.* (1987) reported that data from many workers suggest sea-level to have been near the present at about 30 000 BP. Against this must be put the conclusion of Chappell & Shackleton (1986) cited at the beginning of this section. For the time interval involved here their curve would have to be in error by 50 m or more if this third possibility were valid.

The first possibility thus seems able to be discarded or at least regarded with skepticism. The second, of uplift resulting from eruption, remains, but a magnitude of at least 60 m seems rather too large. For the last, that sea-level of the time stood more or less at the present level, there is a body of support indicating that it must be taken seriously. Either this or a combination of volcanism and high sea-level must provide the solution.

PLASTIC DEFORMATION

Whether the *Anadara*-bearing deposit is *in situ* or has been displaced by explosive volcanism, its disposition and attitude described above indicate deformation by the moving lava flow. Whether *in situ* at high tide or displaced upwards from a subtidal level, the deposit would have been within the marine zone ever since formation, with little or no overburden to dewater it. It must therefore have been able to retain sufficient plasticity to permit the deformation now seen.

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APPENDIX I

XRD ANALYSIS OF THE LAPILLI IN R11/f148.

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Disaggregated lapilli were sieved and washed, and volcanic grains over 0.5 mm in diameter were collected. The X-ray diffractogram made from the powdered volcanics was compared with that for a standard synthetic rock powder with known proportions of constituent rockforming minerals. The constituent mineral percentages were roughly estimated by comparing corresponding lines of relative intensities. These results were compared with those from possible eruption centres in the general vicinity. Results are as follows:

	1	2	3	4	5	6	7	8
Plagioclase	25	60	60	10	25			50
Augite	40	20	30	50	50	50	45	30
Olivine	20	5	5	5	20	5	10	5
Nepheline				5		10	25	

1 = R11/f148; 2 = Rangitoto Lava (A); 3 = Rangitoto Lava (B); 4 = Motukorea (Brown's Is.); 5 = Onepoto; 6 = North Head; 7 = Mt Victoria; 8 = Pupuke.

The only compositional similarity lies with the Onepoto ejecta. However, ejecta from another possible eruption centre, Tank Farm, have not been tested because of the deep weathering. XRD results show that the lapilli in R11/f148 could have come from Onepoto, but a source at Tank Farm can not be excluded because of the lack of data.